

APPLICATION OF SEISMIC ATTRIBUTE ANALYSIS TO ASSESS THE HYDROCARBON PROSPECTIVITY OF CRETACEOUS DEPOSITS IN THE SOUTHERN FERGANA BASIN

***Erkinjon Majidov Karimberdi ogli,**

“Uzbekgeofizika” JSC, Republic of Uzbekistan, Tashkent, Geofizika settlement.

**Author for Correspondence: majidoverkin@gmail.com*

ABSTRACT

This study presents the application of seismic attribute analysis to evaluate the hydrocarbon prospectivity of Cretaceous deposits in the eastern sector of the southern margin of the Fergana Basin, using the Xankiz and Xartum–Janubiy Olamishiq areas as case studies. Three-dimensional common-depth-point (3D CDP) seismic data, well logs, and well-test results were integrated to interpret the geometric attributes Coherence and Relief, the amplitude attribute root-mean-square (RMS) Amplitude, and the amplitude–frequency attributes Sweetness and Instantaneous Frequency. Coherence and Relief were used to refine the interpretation of fault continuity and the geometry and morphology of local structures, whereas amplitude- and frequency-related attributes were applied to delineate potential reservoir intervals. Comparison with wells that encountered productive formations in the Xankiz field indicates that intervals showing spatially coincident high RMS Amplitude, high Sweetness, and relatively low Instantaneous Frequency may serve as additional seismic criteria for screening prospective targets. These anomalies, however, do not constitute direct evidence of hydrocarbons and require validation against independent geological and geophysical data.

Keywords: *Fergana Basin; Cretaceous deposits; 3D CDP Seismic Survey; Seismic Attributes; Coherence; Relief; RMS Amplitude; Sweetness; Instantaneous Frequency; Reservoir rocks; Hydrocarbon prospectivity*

INTRODUCTION

Identifying low-relief structures, lithologically sealed traps, and combination traps remains a key challenge in exploring for hydrocarbon accumulations within Cretaceous strata along the southern margin of the Fergana Basin. The area is characterized by complex tectonics and pronounced lateral variations in formation thickness and lithofacies, which hinder unambiguous evaluation of prospective zones using conventional seismic sections alone [Abdullaev *et al.*, 2021, Novruzov *et al.*, 2019, Pedder *et al.*, 2016]. Consequently, seismic interpretation needs to be supplemented by dynamic and geometric indicators.

Attributes derived from 3D CDP seismic data enable the geometric, amplitude, phase, and spectral characteristics of the seismic wavefield to be assessed both individually and in combination. They may reveal changes in reflector continuity, faulting, stratigraphic geometry, and acoustic properties. Nevertheless, because seismic attributes are indirect indicators of subsurface geology, they cannot independently establish hydrocarbon saturation. Reliable interpretation requires integration of attribute responses with well information, stratigraphic boundaries, and the structural model [Korchagin, 2015, Urmonov *et al.*, 2019].

In the eastern part of the southern Fergana Basin margin, reservoir lithology, bed thickness, fault architecture, and potential trap geometry are closely interrelated. The objective of this study is to compare the geological significance of Coherence, Relief, RMS Amplitude, Sweetness, and Instantaneous Frequency in the Xankiz area and adjoining zones, assess their spatial correspondence, and develop integrated interpretation criteria for identifying prospective intervals in the Cretaceous succession.

Research Article

MATERIALS AND METHODS

The database comprised 3D CDP seismic surveys acquired in the area during previous years, well-log measurements, vertical seismic profiling (VSP) data, and well-test results. The investigated Cretaceous succession occurs at depths of up to approximately 4 000 m [Majidov, 2019, 2026]. Well data provided the reference framework for examining the spatial relationship between seismic anomalies and productive horizons.

Coherence and Relief (geometric), RMS Amplitude (amplitude-based), and Sweetness and Instantaneous Frequency (dynamic/frequency-related) attributes were calculated from 3D seismic data using the “Paradigm” software suite and then compared. Interpretation considered (1) the association of attribute anomalies with seismic horizons and faults, (2) their continuity along seismic sections, and (3) their expression around productive wells. Allowance was made for the fact that different attributes may not provide geologically independent evidence.

The Coherence attribute characterizes the degree of waveform similarity and spatial consistency between neighboring seismic traces. High coherence generally indicates comparatively continuous reflectors, whereas low values signify abrupt differences between adjacent traces. Such differences may result from faults, erosional boundaries, lithofacies transitions, or local variations in data quality. Accordingly, low-coherence zones were interpreted as possible faults only after examining their geometry on vertical sections and their consistency with other evidence.

The Relief attribute enhances local uplift, depression, and dip changes in the morphology of reflecting horizons, thereby improving the visibility of subtle structural features. It was used to characterize the spatial expression of structural crests, flanks, and deformation associated with faulting. Relief results were not treated as independent structural maps but as complementary information alongside time sections and Coherence analysis.

The RMS Amplitude attribute is defined as the square root of the mean of squared seismic amplitudes within a selected time window and represents the relative signal amplitude over that interval. Variations may reflect acoustic-impedance contrasts, bed thickness, wave interference, and seismic processing effects. High RMS Amplitude values therefore do not, by themselves, demonstrate the presence of reservoir rocks or fluids.

Sweetness integrates amplitude and instantaneous-frequency characteristics and is commonly used to highlight intervals with high amplitudes and relatively low frequencies. In practice, it is often calculated as the instantaneous amplitude divided by the square root of the instantaneous frequency; the specific implementation and stabilization applied at low frequencies may affect the output. Sweetness anomalies were therefore interpreted as supplementary evidence of possible variations in reservoir properties.

Crossline-2810, which intersects the Xartum and Janubiy Olamishiq fields, was selected to assess the usefulness of geometric attributes. To compare amplitude- and frequency-based attributes against well results, the interval spanning Cretaceous horizons XVII–XVIII in the Xankiz field was examined. A random seismic line, Random_I-I, was constructed through Xankiz wells №51, 48, 34, 36, and 60. Table 1 presents data for five wells with specified test parameters in the source material. The structural map of the Xankiz field is shown in Figure 1.

Well elevations and reported well-test results in the Xankiz field

Table 1

№	Well	Elevation(m)	Reported test results
1	Xankiz № 34	623.00	Horizon XVII (a+b+v): gas, 160.0 thousand m ³ /day
2	Xankiz № 36	620.97	Horizon XVII (a+b+v+g): gas, 150.0 thousand m ³ /day
3	Xankiz № 48	612.00	Horizon XVII (g): gas, 26.0 thousand m ³ /day; condensate, 6.0 m ³ /day
4	Xankiz № 51	613.00	Horizon XVII (g): gas, 75.0 thousand m ³ /day; condensate, 10.0 m ³ /day
5	Xankiz № 60	624.40	Horizon XVII (g): gas, 45.0 thousand m ³ /day

RESULTS AND DISCUSSION

Geometric attributes: refining the tectonic interpretation.

Geometric attributes were analyzed to investigate the spatial continuity, deformation, and fault-related disruption of seismic reflectors. Coherence and Relief outputs were interpreted together with conventional time sections to assess the geological plausibility of features highlighted by individual attributes [8]. This approach helped distinguish potential faults from incidental signal variations associated with low coherence or local relief contrasts.

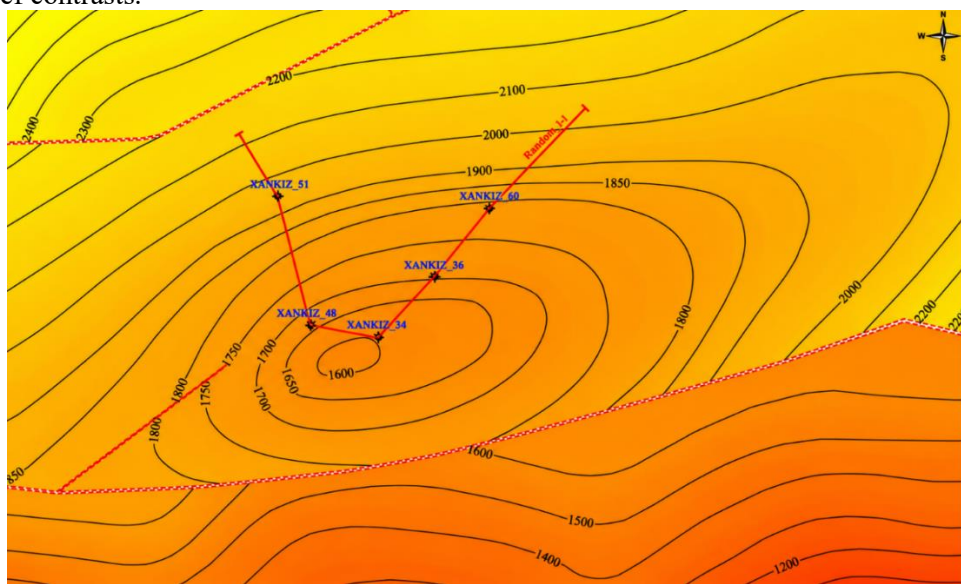


Figure 1. Structural map of the Xankiz field for the Cretaceous deposits (Ustritsa Formation).

Coherence analysis made it possible to delineate certain discontinuities that were poorly expressed on conventional time sections and to assess their orientation and lateral persistence. Areas of reduced similarity between adjacent reflectors were examined further as potential fault zones. Not every such feature was classified as a tectonic fault.

Relief enhanced local geometric contrasts and clarified reflector morphology and associated deformation. When used together with Coherence, particular attention was paid to the spatial correspondence between low-coherence zones and abrupt changes in reflector relief. This cross-check helped support the fault interpretation and refine the boundaries of structural elements.

Geometric variations revealed by Relief were examined on the Crossline-2810 time section crossing the Xartum and Janubiy Olamishiq fields (Figure 2). A combined display of Relief and Coherence along the same profile facilitated comparison of the likely fault orientations, their continuity through the section, and their relationships with seismic reflectors (Figure 3).

The observations indicate that combined Relief and Coherence analysis is useful for verifying the positions of faults identified on conventional time sections, refining their probable continuity, and resolving the morphology of local structures. Nevertheless, geometric attribute responses must be assessed in conjunction with geological interpretation and well data.

Amplitude- and phase/frequency-related attributes and potential reservoir zones.

High values of RMS Amplitude may arise from acoustic-impedance contrasts, bed thickness, wave interference, lithological variations, or fluid-related effects. Accordingly, high-amplitude zones were not assumed to be productive; instead, they were treated as seismic anomalies requiring further investigation of reservoir properties.

Within the 1 600 – 1 800 ms time interval of the Random_I-I profile, a package of relatively high-amplitude reflections is apparent (Figure 4). Its lateral distribution is heterogeneous: reflection intensity increases in

some areas and decreases in others. These features were considered together with reflector geometry, possible changes in bed thickness, and lithofacies variations.

In addition to reflections near productive horizons, the RMS Amplitude section shows local anomalies with similar dynamic characteristics at deeper stratigraphic levels. Their prospectivity was evaluated not solely by amplitude strength but also by structural position, lateral persistence,

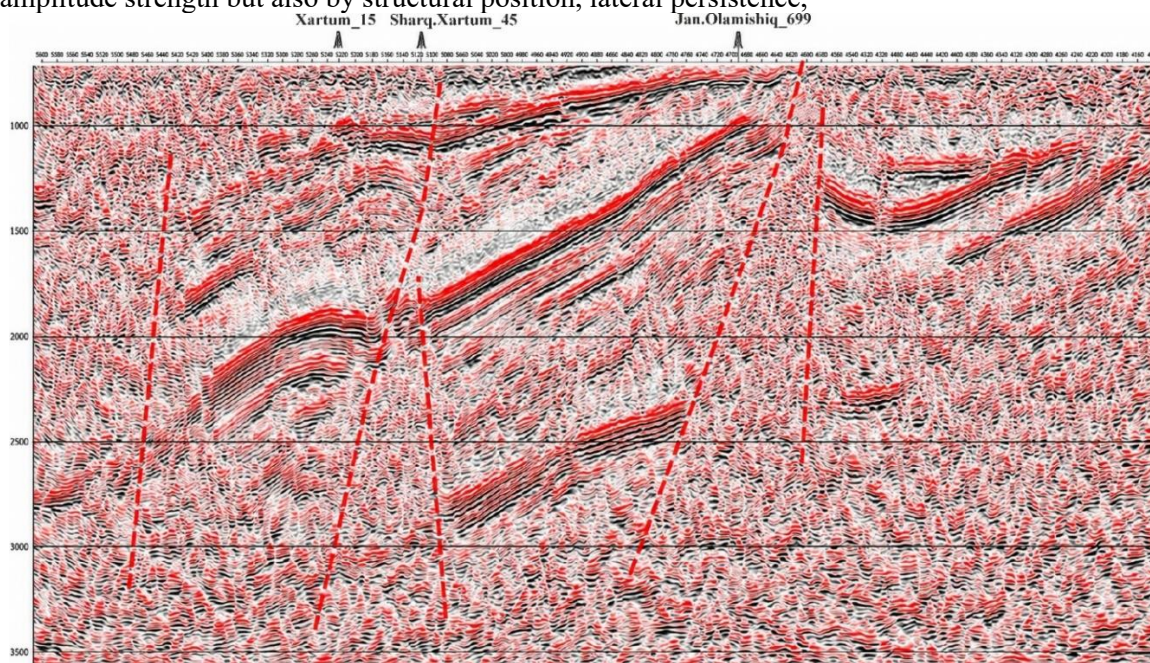


Figure 2. Relief attribute results for delineating tectonic faults on the Crossline-2810 seismic time section.

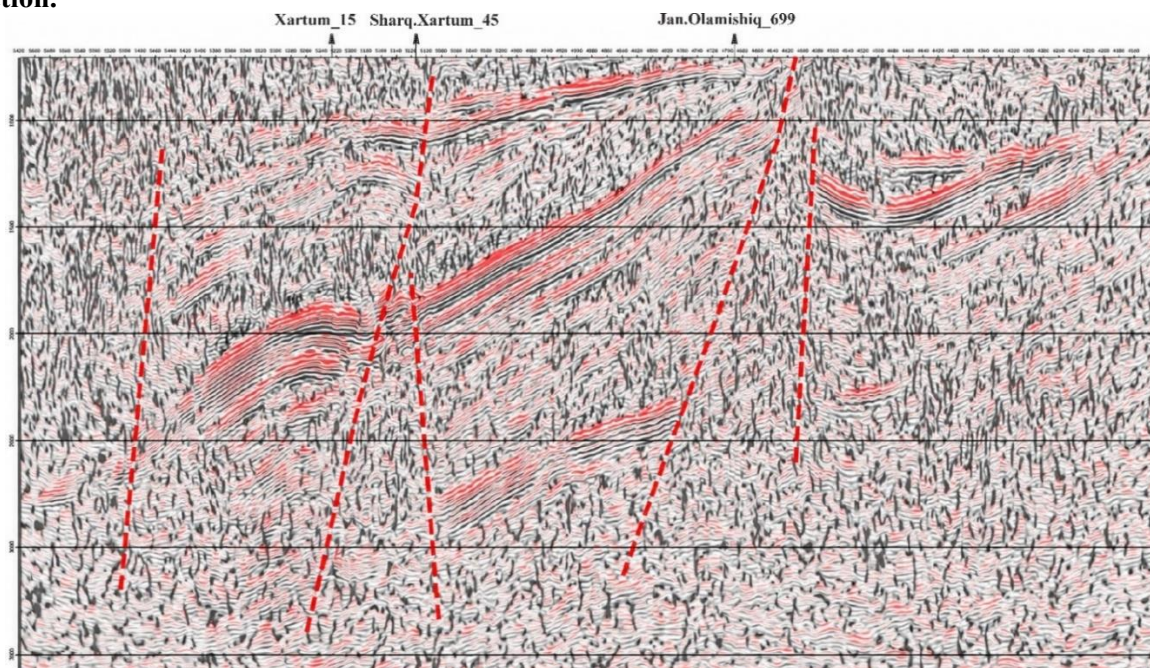


Figure 3. Integrated use of Relief and Coherence attributes to delineate tectonic faults on the Crossline-2810 seismic time section.

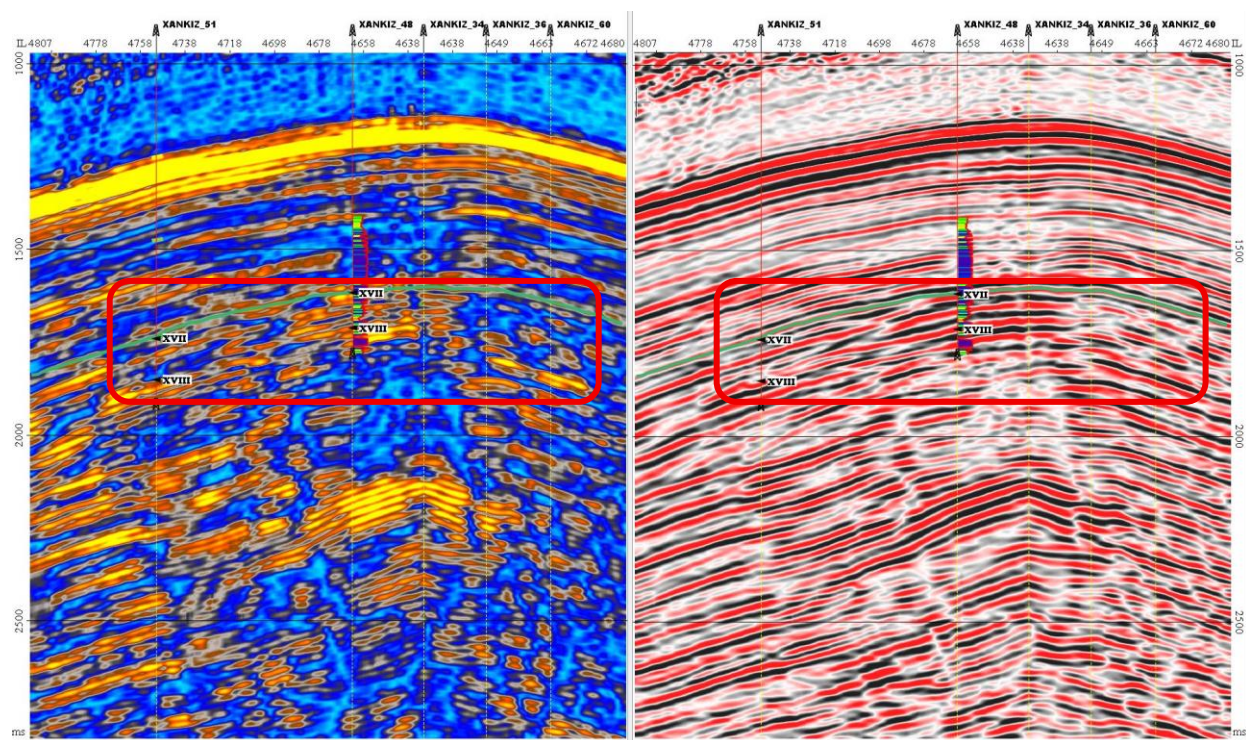


Figure 4. RMS Amplitude attribute along the Random_I-I seismic profile

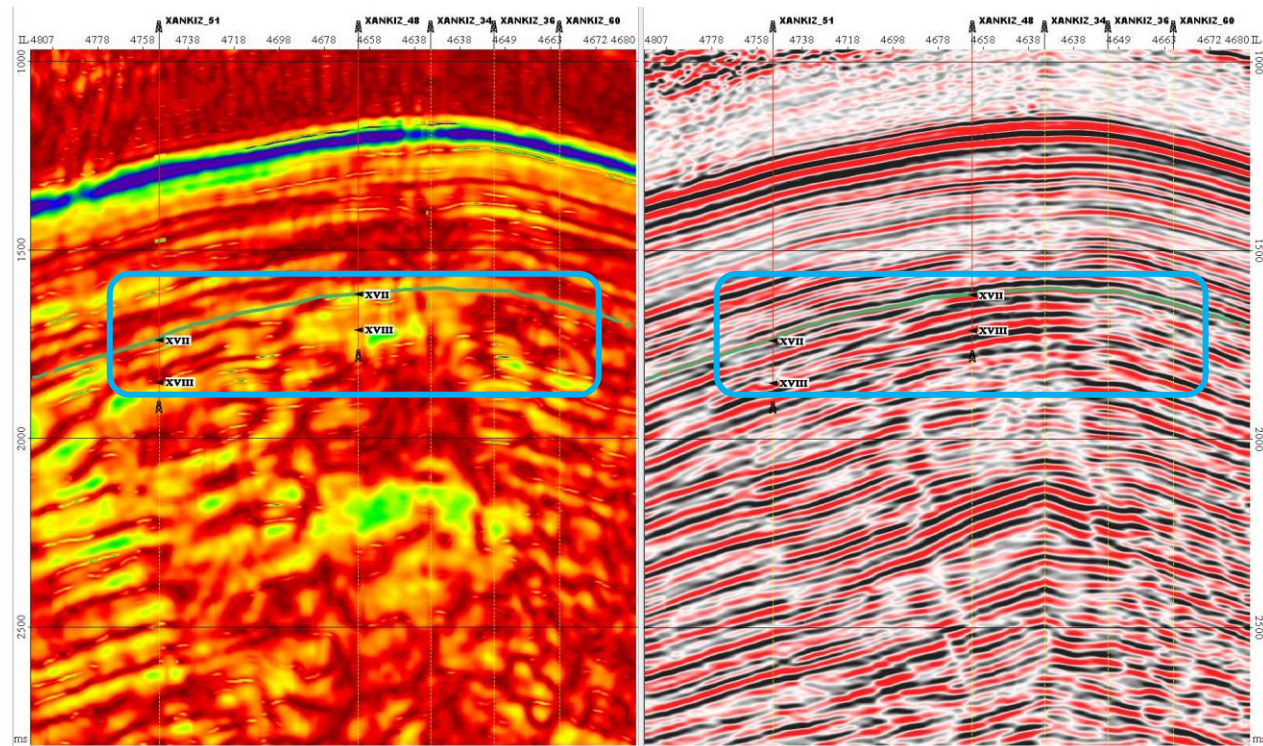


Figure 5. Sweetness attribute along the Random_I-I seismic profile.

Research Article

relationship to reflecting horizons, and correlation with wells. The reservoir characteristics of these zones require additional verification.

To investigate the geological significance of zones delineated by RMS Amplitude, their responses were compared with Sweetness and Instantaneous Frequency. This comparison assessed whether amplitude enhancement coincided with changes in frequency content. Because Sweetness is itself a function of amplitude and frequency, its agreement with RMS Amplitude was not considered wholly independent confirmation.

The comparison showed that some intervals distinguished by elevated RMS Amplitude also exhibited high Sweetness values (Figure 5). Coincident changes in amplitude contrast, frequency characteristics, and reflector geometry provide grounds for further investigating these areas as potential reservoir intervals. Their actual lithological composition and fluid saturation, however, cannot be established conclusively without well data.

High Sweetness values occurring within structurally closed features, anticlinal culminations, or areas of possible fault or stratigraphic sealing are of additional exploration interest. Sweetness anomalies, however, are not direct hydrocarbon indicators. They may also arise from bed thickness, wave interference, lithofacies transitions, signal attenuation, and processing algorithms. Relatively low Sweetness may characterize low-amplitude or higher-frequency reflections and should not, on that basis alone, be equated with clay-rich or tight rocks.

Instantaneous Frequency was compared with RMS Amplitude and Sweetness along the same profile. The relatively lower instantaneous frequencies observed in some high-amplitude areas indicate coincident changes in the dynamic and spectral characteristics of the seismic signal. Such correspondence does not establish a single geological cause; the spatial persistence of each anomaly and its relationship to wells were assessed separately.

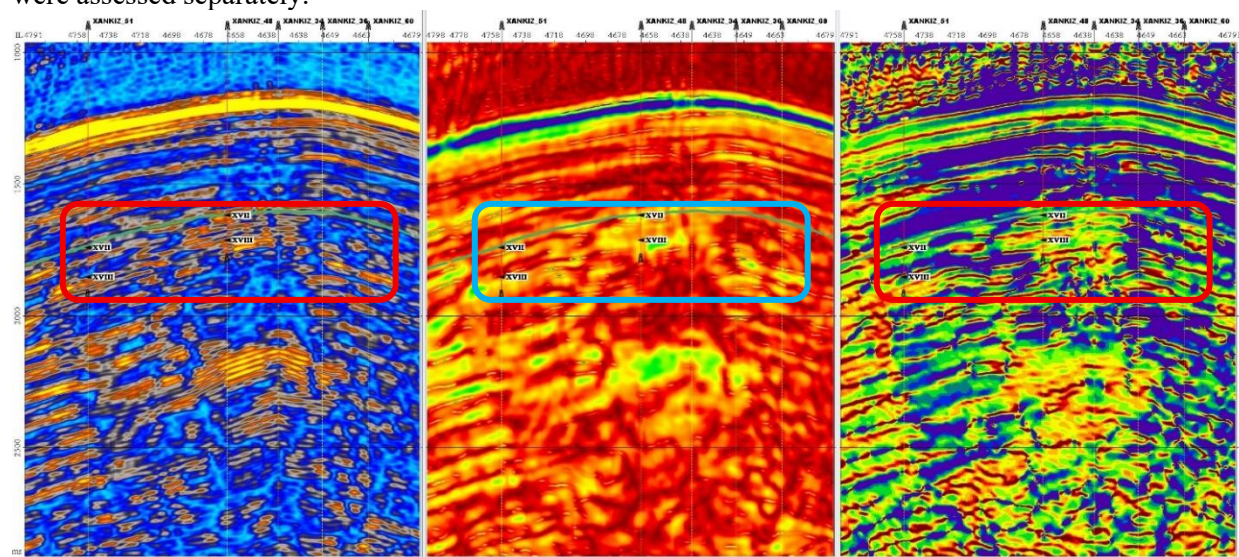


Figure 6. Joint display of RMS Amplitude, Sweetness, and Instantaneous Frequency attributes along the Random_I-I seismic profile.

Instantaneous Frequency estimates the local time-dependent frequency of the seismic signal and is sensitive to localized spectral changes in seismic reflections. Lower frequencies may be associated with attenuation, absorption, bed interference, lithological changes, or processing effects. Low-frequency zones were therefore regarded as auxiliary indicators for screening potential reservoirs in Cretaceous strata; independent petrophysical and geological evidence is needed to establish any fluid-related interpretation.

Research Article

Methodologically, it is unjustified to regard low Instantaneous Frequency as direct evidence of hydrocarbons. Such anomalies may result from bed thickness, reflection interference, lithofacies characteristics, signal absorption, or processing parameters. Consequently, this attribute was evaluated in terms of anomaly continuity along the section, structural position, correspondence with RMS Amplitude, and available well evidence.

To synthesize the results, RMS Amplitude, Sweetness, and Instantaneous Frequency were compared jointly along one seismic profile (Figure 6). This approach enabled assessment of the spatial coincidence of amplitude anomalies and frequency variations, screening of potential reservoir zones, and prioritization of areas for subsequent geological and geophysical investigation. Interpretation remained cautious because the attributes may be mathematically and physically interdependent.

CONCLUSIONS

The results demonstrate that Coherence and Relief were useful for refining the interpretation of tectonic faults and local geometric variations on Crossline-2810 between the Xartum and Janubiy Olamishiq fields. Along Random_I-I in the Xankiz area, several intervals displayed spatially coincident high RMS Amplitude, high Sweetness, and relatively low Instantaneous Frequency. When such correspondence occurs in a favorable structural setting, it provides a basis for prioritizing potential reservoir zones for further investigation.

The combined RMS Amplitude–Sweetness–Instantaneous Frequency approach thus has practical value for the integrated characterization of the dynamic and frequency-related properties of Cretaceous deposits and for preliminary screening of targets for oil and gas exploration. Wells yielding gas and gas-condensate flows in the Xankiz field provided geological reference points for interpreting the attribute responses. Nevertheless, definitive conclusions regarding reservoir quality or hydrocarbon saturation require further validation through well logs, test results, petrophysical analysis, and, where appropriate, seismic inversion. On the available evidence, the identified anomalies should be regarded as indirect indicators of prospectivity.

REFERENCES

- Abdullaev G.S., Bogdanov A.N. and Eydelnant N.K. (2021).** Current status and development prospects of geological exploration for oil and gas in the Fergana region of the Republic of Uzbekistan. *Oil and Gas Geology: Theory and Practice, St. Petersburg*, **16**(2), 1–26.
- Korchagin O.A. (2015).** On attribute analysis in seismic exploration: Attributes of reflected and scattered waves. *Proceedings of the International Kazakhstan Conference, Kazakhstan*, pp. 49.
- Majidov E.K. (2019).** Seismic investigation of Cretaceous deposits in the Fergana Basin. *Geology and Mineral Resources, Tashkent*, **4**, 69–71.
- Majidov E.K. (2026).** Refinement of reflecting boundaries within Cretaceous deposits on the southern step of the Fergana Basin using 3D CDP and VSP data. *International Journal of Geology, Earth and Environmental Sciences, Jaipur, India*, **16**, pp. 126–130.
- Novruzov A.G., Gadirov V.G. and Urmonov A.X. (2019).** Prediction of oil and gas accumulations on the southern margin of the Fergana Basin using an integrated set of geophysical methods. *SOCAR Proceedings, Baku*, **2**, 23–30.
- Pedder Yu.G., Gadoev A.I., Muminov M.N. and Mamirov, J.R. (2016).** Non-structural traps in Mesozoic-Cenozoic deposits of the southern step of the Fergana Basin: Underexplored prospective targets for discovering new oil and gas accumulations. *Proceedings of the Republican Scientific and Practical Conference, Tashkent*, 43–46.
- Urmonov A.X. and Majidov E.K. (2019).** Hydrocarbon prospectivity of Cretaceous deposits in southeastern Fergana. *Proceedings of the International Scientific and Practical Conference, "Institute of Geology and Exploration of Oil and Gas Fields" SI, Tashkent*, 76–79.

Research Article

Yuldashev G.Yu. and Majidov E.K. (2024). Innovative approaches to interpreting geophysical surveys for identifying new oil and gas prospects in the Cretaceous deposits of the Fergana Basin. *Journal of the National Association of Scholars (NAS), Engineering Sciences, St. Petersburg*, **1**(105), 41–45.